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(54) **Propulsion apparatus**

(57) A duct 4 is provided on the suction side of a ship's propeller with blade tips having barrier plates 3 extending transversely therefrom, the duct being arranged to direct a fluid stream in substantially shock-free contact with the plates. When the propeller is rotating, the plates 3 describe a body of revolution which substantially constitutes an extension of the after side of duct 4.

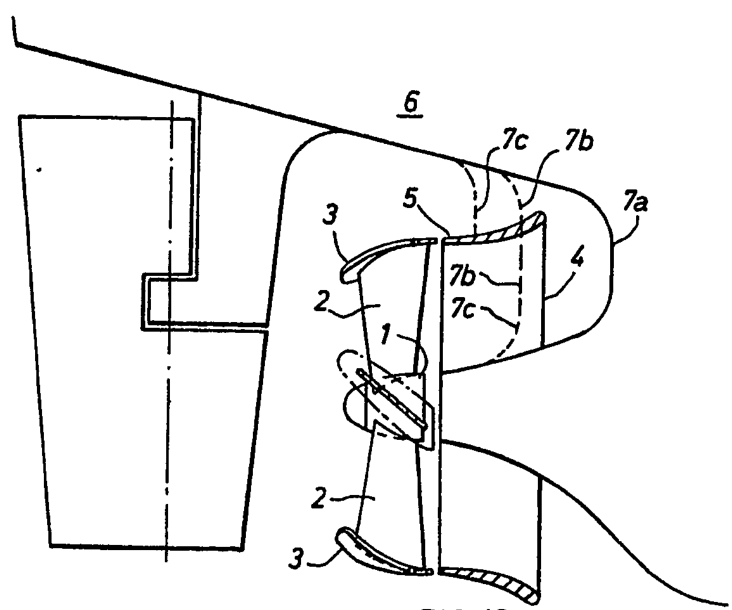


FIG.10.

GB 2 063 378 A

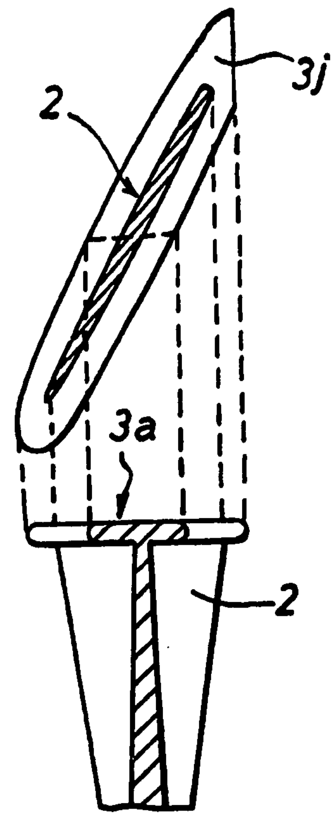


FIG. 1.

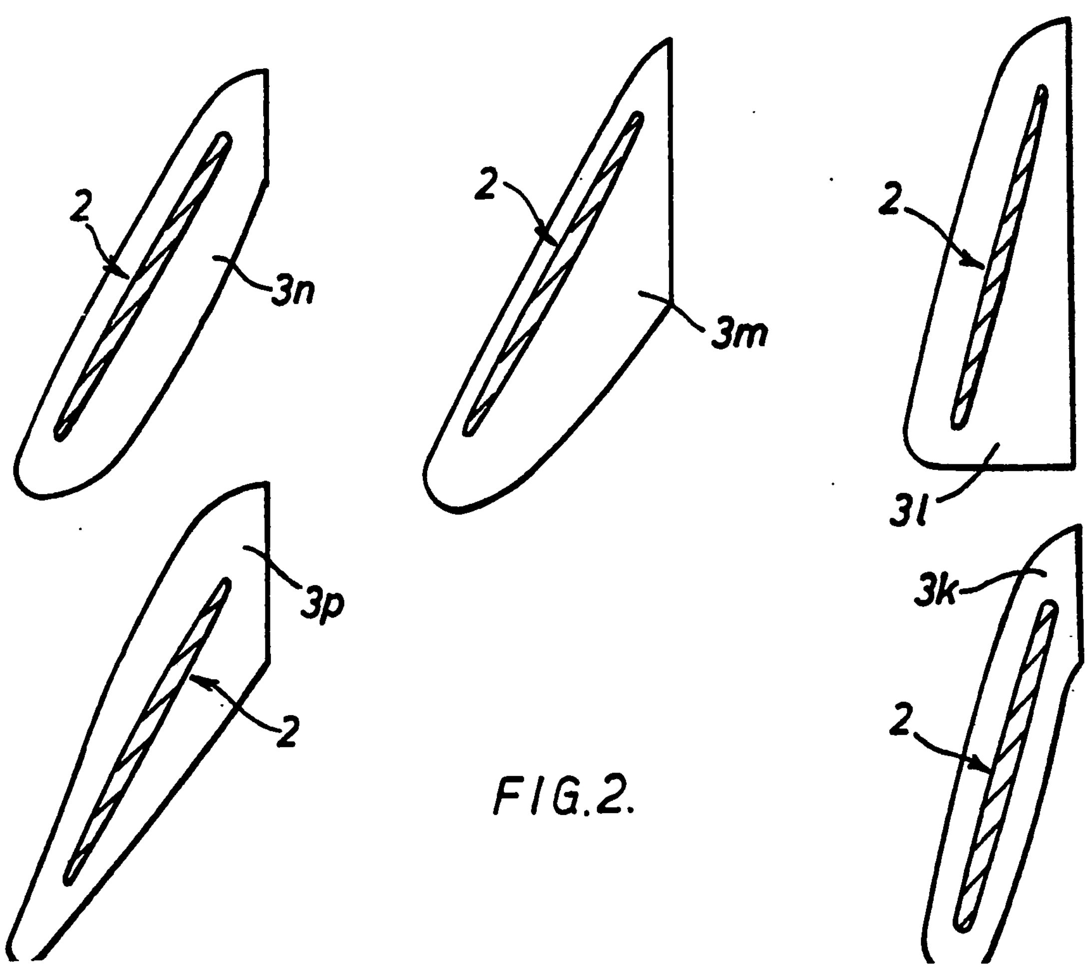


FIG. 2.

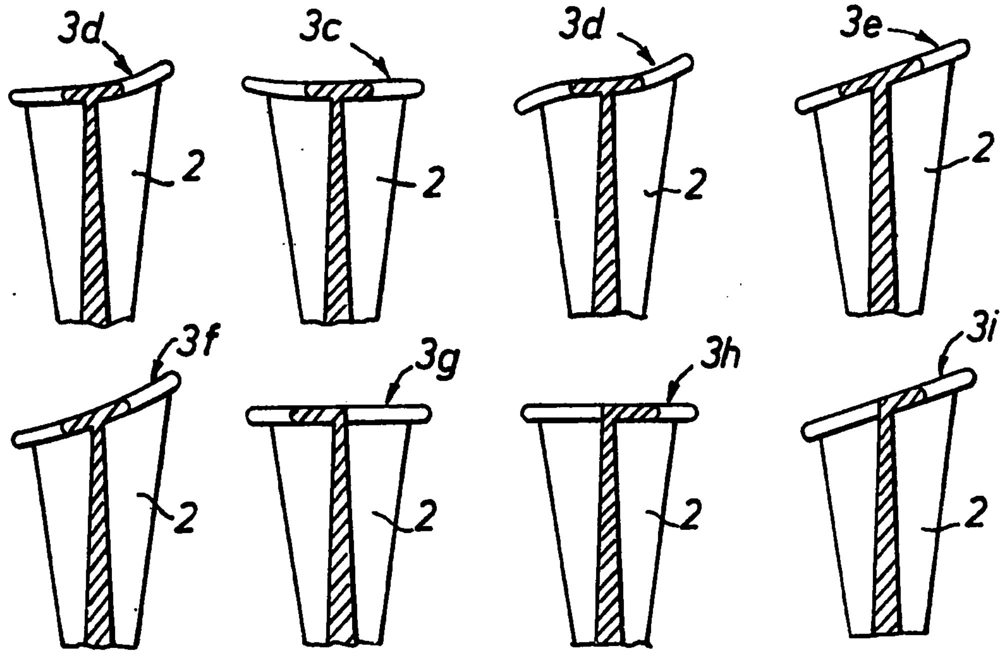


FIG.3.

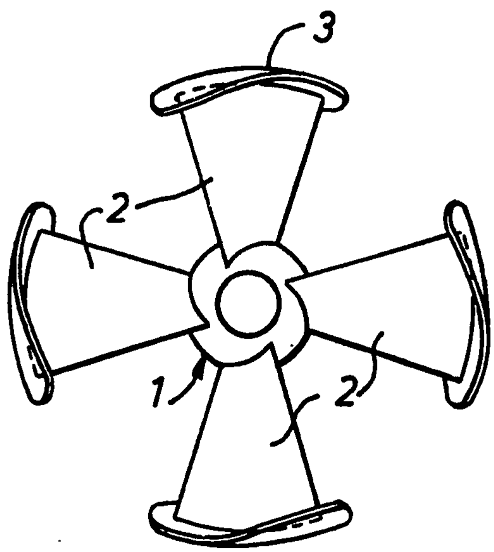


FIG.4.

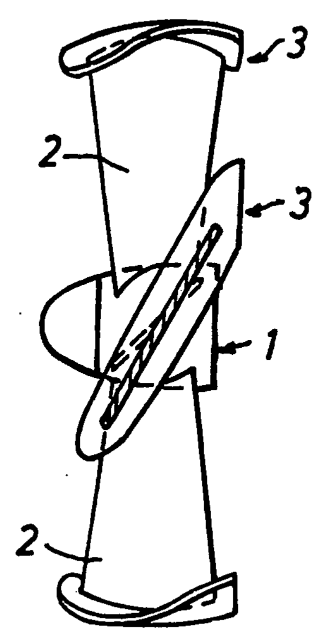


FIG.5.

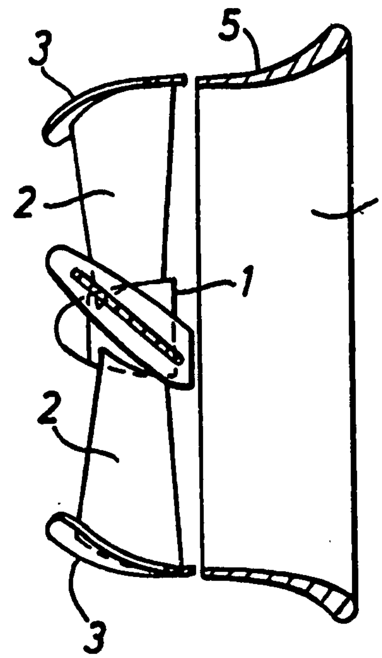
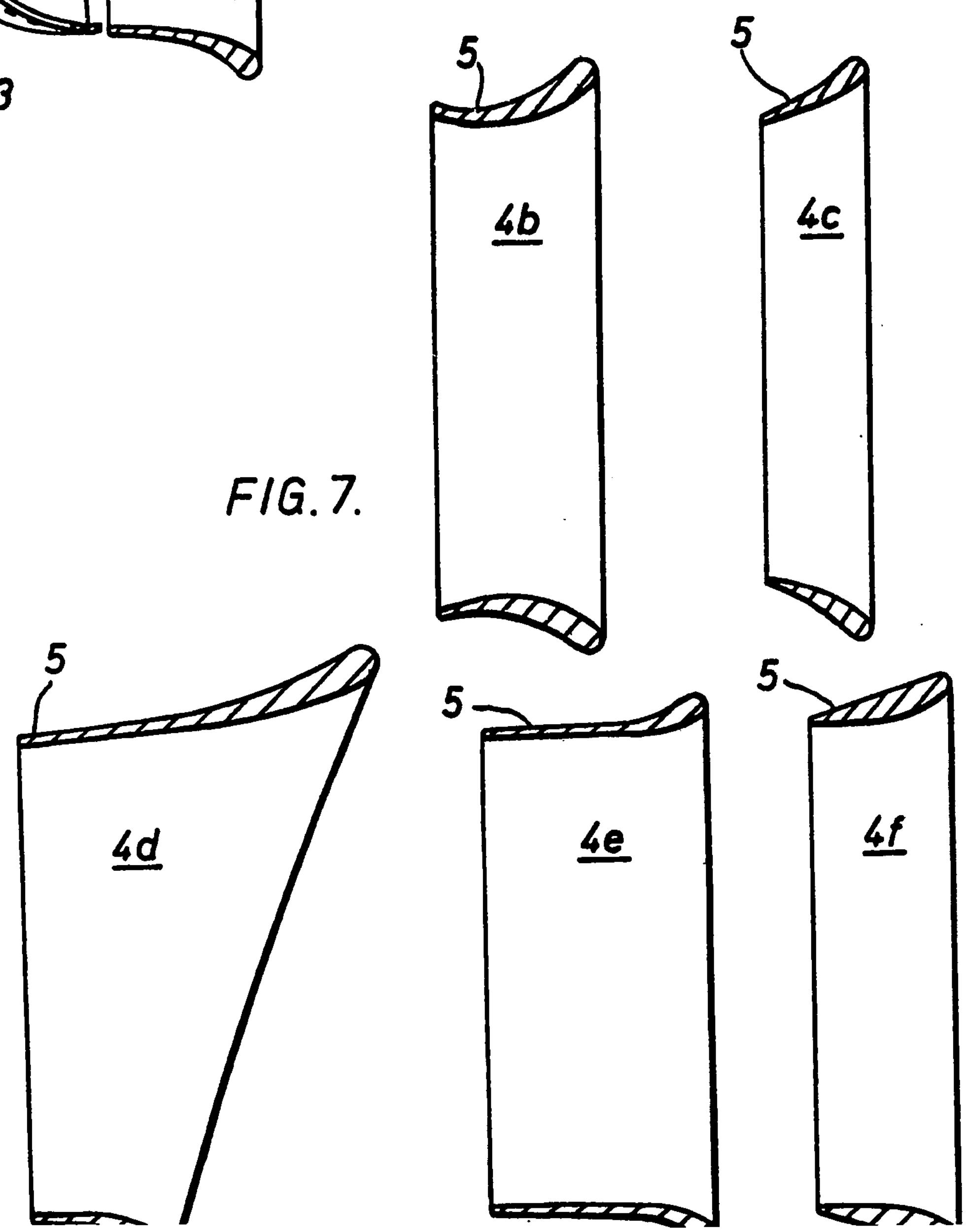


FIG. 6.

FIG. 7.



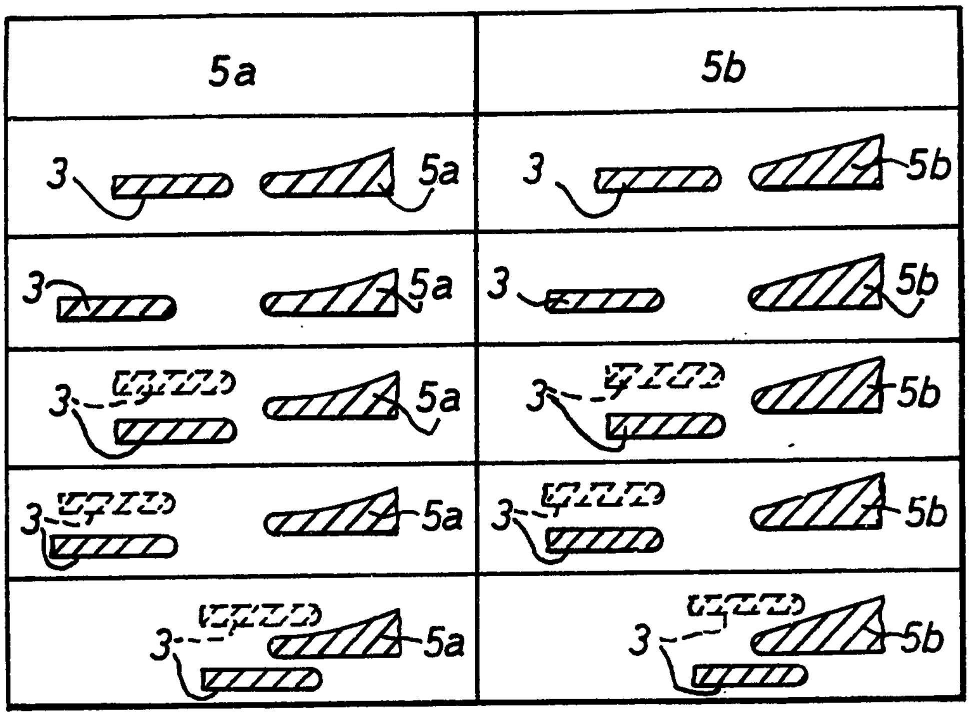


FIG 8.

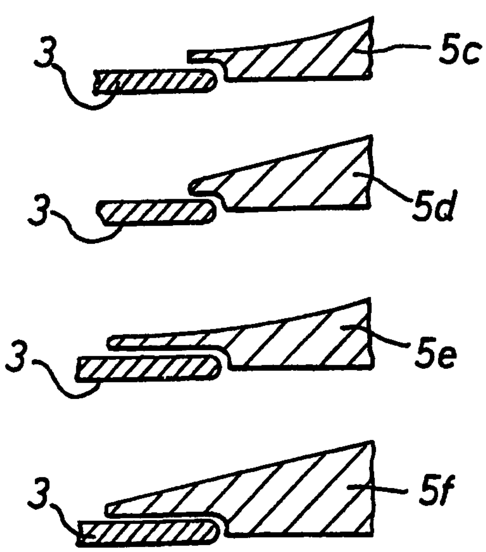


FIG. 9.

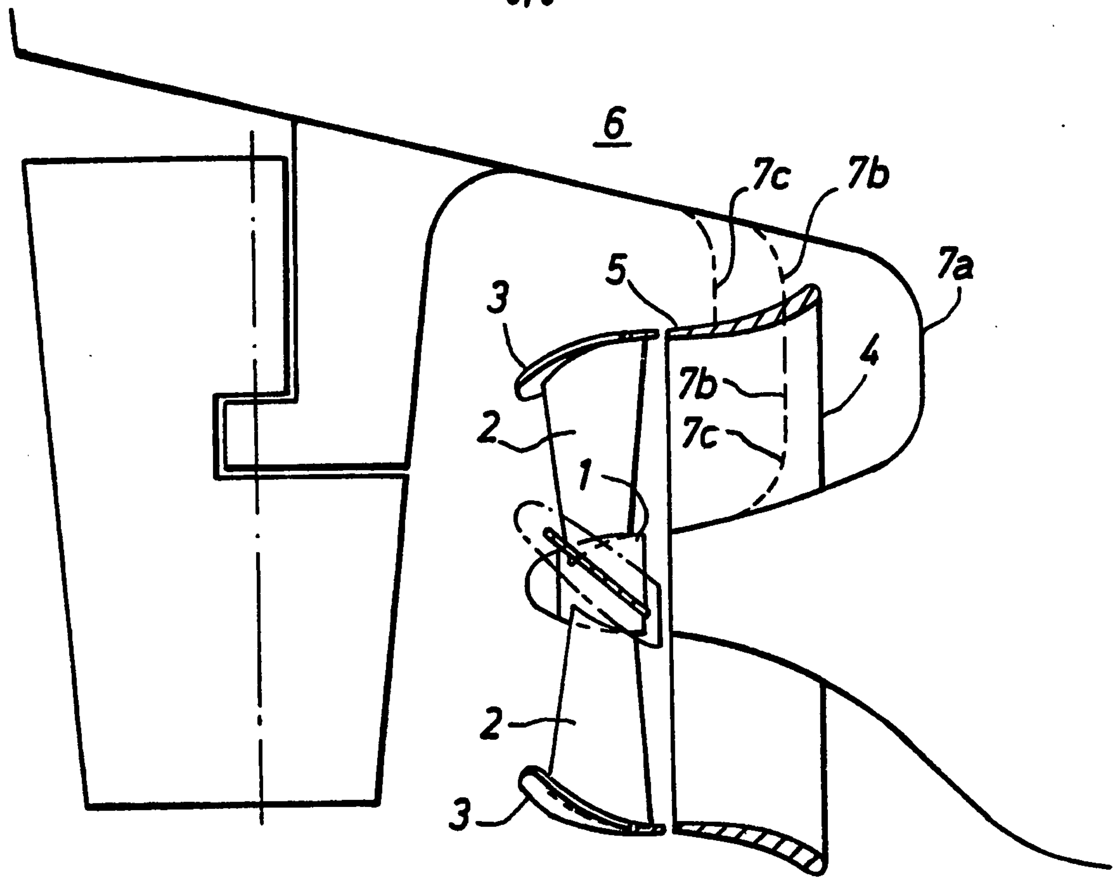


FIG.10.

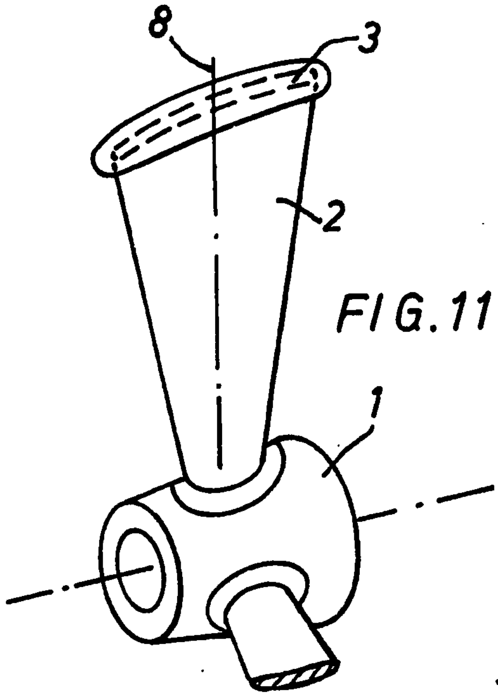
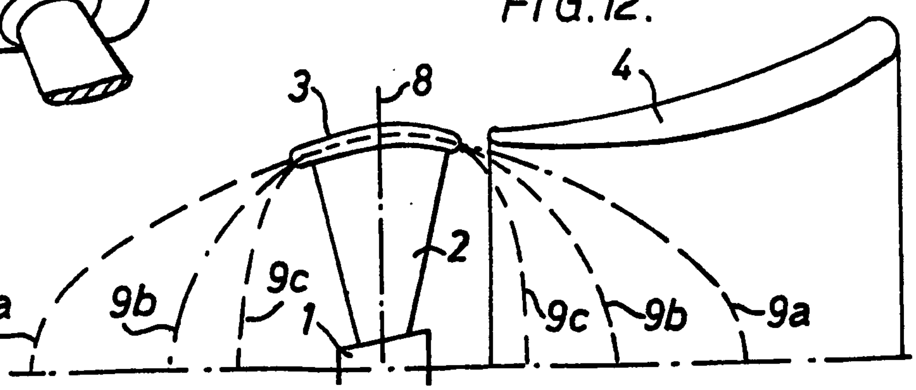


FIG.11.

FIG.12.



SPECIFICATION

Propulsion apparatus

The invention relates to propulsion of ships by means of propellers having blades with tip barrier plates.

The invention is applicable to fixed blade propellers and also to orientatable blade (controllable pitch) propellers. The geometrical definitions herein included refer, for the orientatable blade propellers, to the position of the blades corresponding to the design pitch condition.

To impart finite circulation (or loading) values to blade tip sections of a ship's propeller, it is necessary to give the propeller blades a very special geometry involving an uncommon pitch distribution along the radius, but this alone is not sufficient, since in addition it is also necessary to prevent the formation of vortices at the tips of the blades. To achieve this, it is known that the following techniques may be employed:

(a) making the propeller operate inside a fixed nozzle or duct having circular cross-sections which are coaxial with the propeller, although with this technique tip vortices are not completely eliminated, owing to the necessary clearance existing between blade tips and inner surface of duct;

(b) connecting such a duct to the propeller blade tips, so that the duct rotates together with the propeller, although with this technique the efficiency of the propeller is very substantially reduced, because of the high viscous resistance of the rotating duct;

(c) adding barrier or closing plates to the tip sections of the propeller blades, which plates can be imaged as cut out from an ideal surrounding duct like the one mentioned in (a) or (b) above.

Even when propeller blades are given the very special geometry which is required to get effectively finite circulation (or loading) at the tip sections, and are fitted with transverse barrier plates extending from the tips of the propeller blades so that, from a theoretical viewpoint, finite circulation (or loading) values should be obtained at the tip sections of the propeller blades, such circulation (or loading) is not actually attained in practice because of the flow separation phenomena produced when the fluid contacts the barrier plates on the blade tips of the propeller while the propeller is driving a ship. Consequently, the performance of this type of propeller has been always unsatisfactory up to now, its efficiency being lower than the efficiency of conventional propellers.

However, we have now found that the low propulsive efficiency of this type of propellers is dramatically improved when the incoming fluid stream contacts the barrier plates under shock-free conditions regardless of the ship's speed and the revolution rate of the propeller, so that the above-mentioned flow separation phenomena are avoided.

With the aim of achieving such shock-free conditions in practice, the invention provides propulsion apparatus comprising the combination of a ship's propeller of fixed blade or orientatable blade type (the geometrical definitions hereinafter included referring in this case to the design pitch condition) in juxtaposition with a non-rotating duct, the propeller having an axis, a diameter and a plurality of blades, each blade having (a) a basic generative line, (b) a fixed plate at the tip section, and (c) a back or suction side, (d) the duct being coaxial with and displaced from said propeller and located on the back or suction side thereof, (e) its after or downstream side being an extension of a geometric figure ideally generated (by a cross-section of an axial plane, through the basic generative line of a blade, with the fixed plate) on rotation of said fixed plate about the axis, (f) having an internal radius at a point adjacent to the fixed plate which is approximately that of said geometric figure at a point which is closest to said duct, (g) providing means to direct a fluid stream toward said back or suction side of said propeller in substantially shock-free contact with each fixed plate, and (h) having a length at its shortest point which is at least 5 percent of the propeller diameter and at most 2 times the propeller diameter.

The propeller preferably has finite circulation (or loading) values in its blade tip sections.

The forward end of each fixed plate is preferably displaced by at least 5 millimetres from the after or downstream side of the duct. Preferably, the said forward end is as close as possible to the said after side or is even overlapped with it.

The duct preferably has a streamlined configuration. Typically, the duct will have a cross-section which varies in size and/or configuration along its axis. The duct may have a constant length or may vary in length, around its periphery. If the duct varies in length along is periphery, preferably its largest dimension, which may be extended forward in the form of fins, is its highest elevation along the hull and its shortest dimension is at its lowest elevation along the hull.

The invention also provides a method of increasing the propulsive efficiency of a propeller-impelled ship, wherein the propeller has blade tips with fixed barrier plates and is designed to have finite circulation (or loading) values at the blade tip sections, which comprises directing a substantially shock-free fluid stream to and past the barrier plates.

Preferably, the method includes providing ducting means to direct the fluid stream to an area circumscribed by the barrier plates, e.g. by extending the barrier plates with a non-rotatable duct.

With orientatable blade (controllable pitch) propellers, the blade barrier plates may be designed so as to still fulfil their role at any blade position, in spite of the fact that they become out of the extended surface of the after part of the duct when each blade turns around its shaft. Preferably, each blade barrier plate is tangent to a surface of revolution which has the same axis as

the turning shaft of the corresponding orientatable blade of the propeller, in such a way that the said revolution surface is also tangent to the duct surface, and then as a consequence thereof the waterflow coming from the duct will enter in contact with the barrier plates under practically shock-free conditions, at any position of the blades.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows a propeller blade having a barrier or closing plate projecting substantially transversely from the blade tip, the lower part of the Figure being a developed and expanded side view on which a longitudinal section is superimposed, and the upper part being a developed and expanded radial view;

Figure 2 shows five views similar to that in the upper part of Figure 1, being alternative shapes;

Figure 3 shows eight views similar to that in the lower part of Figure 1, being alternative shapes;

Figure 4 is a schematic aft view of a propeller;

Figure 5 is a schematic view of a propeller;

Figure 6 is a schematic side view of a propeller in combination with a fixed duct shown in axial section;

Figure 7 shows five alternative ducts in axial section;

Figure 8 shows, in tabular form, various possible positions of the forward end of a barrier plate in relation to two possible designs of the trailing edge of the duct, in axial section, alternative positions being indicated in broken line;

Figure 9 shows a further four possible designs of the trailing edge, in overlapping the forward end of a barrier plate, in axial section;

Figure 10 is a schematic side view of the underwater part of the stern of a ship fitted with a propeller and a duct, shown in axial section;

Figure 11 is a fragmentary perspective view of a propeller with orientatable blades; and

Figure 12 is a schematic radial section through the propeller of Figure 11 and a duct.

In order to make sure that finite circulation (or loading) is attained in practice at the blade tip sections of a ship's propeller having blades 2 with substantial transverse projections 3 from the blade tips (barrier or closing or tip plates), a non-rotating duct 4 is placed forward (upstream) of the propeller. The after (downstream) end or trailing edge of the duct has a circular section which is specifically adapted to the propeller. The purpose of the duct is to direct the fluid (passing therethrough) in shock-free conditions and as smoothly as possible towards the barrier plates 3 at the tip sections of the propeller blades. The shape of the after end of the duct is designed so as to constitute an effective extension of the surface generated by the barrier plates while the propeller is rotating.

The duct is coaxial with and displaced from the propeller. It is naturally on the back or suction side of the propeller so that it will direct towards the propeller the fluid open which the propeller acts.

The barrier plates 3 may be variously designed, as exemplified by elements 3*a* to 3*i* and 3*j* to 3*p* (in any combination) in Figures 1 to 3, the various designs generating different geometric figures on propeller rotation. The barrier plates are so designed that the intersection with the ideal middle surface of the barrier plates of a plane perpendicular to the axis of the propeller is in the form of arc sections of a circle.

The duct can be more or less stramlined in shape. The more streamlined it is, the less are the disadvantages produced in towing resistance to the ship due to incorporation of the duct.

The actual form of the duct and its precise relationship to the propeller are subject to variations in design, as shown by Figures 6 and 7 which illustrate some differently-shaped ducts 4*a* to 4*f*. Diverse relationships are possible between the trailing edge 5 of such ducts and the barrier plates 3 of the propeller with which they are associated (see elements 5*a* to 5*f* in Figures 8 and 9). However, the form of the duct must be such as to avoid flow separation along its inner surface. Also, the form of the duct can be such as to produce more or less acceleration in the water-flow or fluid-stream passing therethrough. For each ship, there will be an optimum degree of water-flow acceleration which will produce the best combination of hull efficiency and propeller efficiency, and the form of the duct can then be designed so as to achieve said optimum degree of acceleration.

Finally, to obtain maximum efficiency from the combination duct-propeller, the shape and the position of the blade barrier plates relative to the trailing edge of the duct, not only axially, but also transversely and radially, should be such as to get the highest duct acceleration consistent with a low barrier plate viscous resistance, while always keeping the necessary ability to prevent the formation of tip vortices and the best conditions of shock-free contact with the barrier plates of the fluid stream coming from the duct.

The combination of duct and propeller described above can be fitted to any kind of ship with any kind of sternframe. The arrangement and positioning of the apparatus into the sternframe area may adopt many different forms. As an example Figure 10 presents a typical arrangement with one of the types of duct 4 inside a very common type of sternframe, several types of the sternframe profile 7*a* to 7*c* in relation to the duct being shown.

The number of blades on a ship's propeller and the number of propellers used to drive a ship vary; the present invention is independent of such variation, i.e. it can be applied to propellers with any number of blades, and can also be applied to each of two or more propellers driving a ship.

In the drawings: element 1 is a propeller hub; element 2 is a propeller blade; elements 3 and 3*a* to 3*p* are barrier or closing plates; elements 4 and 4*a* to 4*f* are ducts; elements 5 and 5*a* to 5*f* are trailing edges of ducts; element 6 is a ship's hull;

elements 7*a* to 7*c* are sternframe profiles; element 8 is the blade turning axis of an orientatable blade (Figures 11 and 12); and elements 9*a* to 9*c* are surfaces of revolution about the turning axis.

The invention involves forcing fluid contacting tip sections of the propeller blades to make such contact in a direction substantially parallel to the orientation of the barrier plates extending from such tip sections. The invention further involves increasing the propulsive efficiency of a propeller having blades designed to have finite circulation (or loading) values at their tip sections and having blade tips fitted with fixed barrier plates, by directing a fluid stream to and past the barrier plates in a substantially shock-free manner.

Although propeller blades 2 are designed to have the required special geometry to achieve finite circulation (or loading) at their tip sections, and although the tip sections are provided with barrier plates, such as 3*a* to 3*i* and 3*j* to 3*p* (or combination thereof), to permit having finite circulation (or loading) values at such tip sections, the desired circulation is not actually achieved in practice merely by providing such special geometry and such barrier plates. To provide suitable conditions for obtaining such circulation, a shock-free stream must be directed in contact with and past the barrier plates. Such shock-free flow is achieved by providing a duct, such as 4*a* to 4*f*, immediately upstream of the propeller blades. The duct must be suitably adapted to the propeller design and to the hull lines, and also suitably cooperating with the propeller blade tip barrier plates in a manner such as those illustrated in Figures 8 and 9, this cooperation being of paramount importance for the efficiency of the propeller.

As described above, the after end of the duct placed forward of the propeller must be a kind of extension of the geometric surface ideally generated by the propeller blade barrier plates when rotating (or vice versa).

In the case of a controllable pitch propeller, the above requirement refers to the position of the blades corresponding to the design pitch condition. When the blade orientation is changed, the barrier plates become placed out of the ideal surface which is an extension of the after end of the duct. In such a case, each barrier plate can still fulfil its role, if it remains tangential to a surface of revolution whose axis coincides with the axis of the turning shaft of the corresponding blade of the propeller.

In Figure 11 a propeller having orientatable blades is schematically represented. In Figure 12 the same propeller is represented together with a duct. Also, three possible revolution surfaces 9*a* to 9*c* have been represented, all of them having the same axis as the orientatable blade shaft. The required condition is that each barrier plate 3 be tangent to a revolution surface 6, selected in such a way that the duct surface 4 be also tangent to this very same revolution surface 6, this permitting the waterflow coming from the duct to enter in shock-free conditions.

CLAIMS

1. Propulsion apparatus comprising a propeller and a separate duct for directing a fluid stream towards the suction side of the propeller, the propeller having a plurality of blades, each having a fixed plate at its tip section, the duct being coaxial with the propeller and located on its suction side, the downstream end of the duct substantially constituting an extension of a geometric figure generated — by a cross-section of the fixed plate in an axial plane containing the basic generative line of the blade — on rotation of the propeller, the internal radius of the duct at a point adjacent to the fixed plate being substantially equal to the internal radius of the said geometric figure at a point adjacent to the duct, the duct serving to direct the fluid stream towards the propeller in substantially shock-free contact with each fixed plate, the length of the duct or its length at its shortest point being at least 5% of the propeller diameter and at most 2 times the propeller diameter.

2. Apparatus as claimed in claim 1, in which the propeller has finite circulation (or loading) values in its blade tip sections.

3. Apparatus as claimed in claim 1 or 2, in which the forward end of each fixed plate is displaced by at least 5 mm from the downstream side of the duct.

4. Apparatus as claimed in claim 1 or 2, in which the forward end of each fixed plate overlaps the downstream side of the duct.

5. Apparatus as claimed in any of claims 1 to 4, in which the duct has a streamlined configuration.

6. Apparatus as claimed in any of claims 1 to 5, in which the duct has a cross-section which varies in size and/or configuration along its axis.

7. Apparatus as claimed in any of claims 1 to 6, in which the duct varies in length around its periphery.

8. Apparatus as claimed in any of claims 1 to 7, in which the propeller is an orientatable blade (controllable pitch) propeller.

9. Apparatus as claimed in claim 8, in which each fixed plate is tangential to a surface of revolution whose axis is the turning axis of the corresponding orientatable blade, the said surface being substantially tangential to the duct surface, whereby the fluid stream coming from the duct will enter in contact with the plates under substantially shock-free conditions at any position of the blades.

10. A ship having at least one propulsion apparatus according to any of claims 1 to 9, the duct being mounted on and fixed to the hull of the ship.

11. A ship as claimed in claim 10, in which the duct varies in length along its periphery, its largest length being at its highest elevation and its shortest length being at its lowest elevation.

12. Propulsion apparatus as claimed in claim 1, substantially as described with reference to the accompanying drawings.

13. A ship as claimed in claim 10, substantially as described with reference to the accompanying drawings.

14. A method of increasing the propulsive efficiency of a propeller having a plurality of blades, each having a fixed plate at its tip section, which comprises directing a substantially shock-free fluid stream to and past the plates.

15. A method as claimed in claim 14, including providing ducting means to direct the fluid stream to a region circumscribed by the plates.

16. A method as claimed in claim 14, including effectively extending the plates with a non-rotatable duct.

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